Table of Contents

Go Back

System Dynamics Student Projects as Quality Improving Process

By
Jose J Gonzalez
Agata Sawicka
Faculty of Engineering and Science
Dept. of Information & Communication Technology
Agder University College
Grooseveien 36
NO-4876 Grimstad, Norway
Phone: +47 37 25 32 40
Fax: +47 37 25 31 91
Email: Jose.J.Gonzalez@hia.no URL: http://ikt.hia.no/josejg/

Abstract

We have been teaching system dynamics to Master students of Information and Communication Technology and Master students of Industrial and Information Management for six years. To improve the quality of student performance in the courses we have defined student projects requiring as first step in the project work an explicit definition of project goals and formulation of quality criteria for self-evaluation of the projects by the students. Students are required to apply the self-evaluation criteria to guide their project work and to include in their report a final evaluation of their project.

We describe our methods and how our approach has improved from insight derived from our experiences.

Generally speaking the students' quality of work improves during the term and the examination grades are consistently and repeatedly better than for traditional approaches in past experiences. On the other hand, a significant number of the students complain that the system dynamics course demands from them significantly more effort than what they perceive as justified.

Our approach is still evolving. We are interested in criticism and potential collaboration with other institutions.

Introduction

After introducing students to the basic concepts of system dynamics, most books (and, probably, most courses) confront students with challenges comprising in more or less rudimentary form the elements of real life projects. Certainly, this is the case with four popular books that we have used since we started teaching system dynamics at Agder University College in 1997 (Coyle 1996; Maani and Cavana 2000; Richardson and Pugh 1981; Sterman 2000).

It is not easy to teach students system dynamics modelling: Projects, even at the elementary level taught in introductory system dynamics courses, are quite open-ended. Most Norwegian Master students – probably as most students in comparable levels in other countries – are not prepared to think in terms of open-ended projects. Rather, they are used to solve quite sharply delimited exercises. As a consequence, system dynamics projects can be a frustrating experience for both students and teachers.

This paper is a modest attempt to describe an approach that we have been developing during the last five years. It is modest in the sense that we do not aspire to propose a finished product. Rather, we hope to instigate a discussion with colleagues and hopefully to initiate a collaboration leading to a better teaching process.

The paper consists of three parts: First, we describe the general structure and content of the SD courses at Agder University College. Next, we discuss the approach employed for evaluation of the student work. The followed approach is illustrated with a few examples of the actual student projects and the accompanying evaluation schemes. Finally, we discuss briefly the strengths and weaknesses of the employed approach, outlining some of the directions for its future development.

System Dynamics Course at Agder University College

System dynamics is taught as part of two Master studies at the Faculty of Engineering and Science of Agder University College System Dynamics: 1) Master study in Information and Communication Technology; 2) Master study in Industrial and Information Management.[1] Each course has 10 ECTS[2] credits (one third of the total for a half-year term). The number of students in each course is typically around thirty.

Our system dynamics courses consist of a common part (about 70%) dedicated to the basics of system dynamics (corresponding roughly to Ch. 3-9 of Sterman's book) followed by a final part (approximately 30% of the course) dedicated to applications to information security and applications to supply chains for respectively Information & Communication Technology and Industrial & Information Management students. The stuff related to supply chains is taken mostly from Sterman's book (Ch. 17-20). For security we use selected parts of a recent collection of papers (Gonzalez 2003).

Although the courses are taught orally in Norwegian, all written course materials (viz. PowerPoint slides, and all exercises and projects) are in English. Students are also encouraged to write in English as much as possible in assignments, projects and examination papers. Many students do so.

Typically up to five assignments are obligatory projects during the lecture period. This implies that students are required to pass those assignments in order to be allowed to take the final course examination.

In the Norwegian university system it is possible that projects are solved in small groups. The grade is assigned to the group, which also does imply that all students in a given group get the same grade. It is also possible to have a group project as final examination paper. Students get approximately one week's time to execute the project (implying delivering a project paper per group). Again a grade is assigned to

[1] The Master study in Industrial and Information Management is given in cooperation with the faculty of Social Sciences.

[2] ECTS – European Credit Transfer System (http://europa.eu.int/comm/education/programmes/socrates/ects_en.html).

the group. Despite some potential weaknesses (e.g. unequal contribution by different group members, communication across groups, etc.) the general consensus is that such procedure is desirable and works out fine for special subjects.[3]

The total grade achieved during the course counts 25% to the final course grade. In other words: The final examination project, which can come up to five weeks after the lecture period has finished, contributes 75% to the total course grade.

Project-based assignments requiring active application of the new knowledge are a common form for evaluation in academic courses.[4] Thirty years of teaching experience for one of us (JJG)[5] have formed the following impression:

- As evidenced by the submitted reports and papers, most students are not accomplished readers of assignments and examination papers – important points are overlooked or misunderstood.
- Many students don't have a clear idea of the quality of the report or paper they deliver.
- Pure grading – i.e. just giving the student a mark such as A, B, C … (even if it is finer graded, such as A^+, A, A^-, B^+, B, B^-, …) – is not very helpful as "feedback." (Students do not improve much from such "feedback".)

To address these deficiencies, over the past five years we have been constantly revising our approach to evaluating the students' progress. As we learned from mistakes and experiment with new variants, our approach has been changing from year to year. In the following section we discuss briefly the evolution as well as the scheme deployed during the most recent semester (i.e., Spring 2004).

Towards an effective procedure for evaluation of student projects

A typical evaluation regime for the in-course[6] assignments involves two phases:

1. Assignment distribution to students followed by a period during which the course coaches may be consulted
2. Assignment report delivery by the students followed by feedback in a form of grade given by the course coaches.

As indicated at the end of the previous section, this typical approach however provides the students only with a limited insight into their progress; it fails to indicate which areas need further improvement.

To address this weakness, the final grade for the SD in-course assignments was supplemented by a short discussion of the students' work strengths and weaknesses. Despite the enhanced evaluation feedback, we did not notice a substantial improvement in the quality of student work.

---

[3] In our Master studies only about 10-20% of the courses use group student projects as basis for grading.

[4] The assignment-based evaluation is commonly used also in the SD education (see e.g. UiB, MIT course). Also most of the student 'challenges' in Sterman's SD textbook have a form of a typical academic assignment.

[5] Of these thirty years, the first twenty five concern teaching physics (1971-1983) and computer science (1984-1996).

[6] By "in-course" we mean obligatory projects during the lecture period.

In Spring 2002, instead of grading the in-course assignments we introduced a pass-fail scheme. The students were required to submit a short written report along with the developed simulation model. To pass the assignment, the students had to deliver:

- a **complete** report (i.e. a report that covers all the questions formulated in the assignment), and
- a **correct** model.

In case of an incomplete or erroneous delivery, the students were asked to improve and resubmit their work. This evaluation scheme proved to be quite time-demanding both on the part of the students, and the course coaches.[7] On the other hand, it demonstrated that in most cases, **a number of iterations are needed to obtain the basic minimum**: Despite the fact that the students had approximately 3 weeks to work on the assignment and consult with the course coaches, all but one of the 16 student groups were asked to resubmit their work.[8]

To help the students to improve the quality of their work in the following academic year (i.e., 2002/2003), we modified the assignments' evaluation procedure. Now, the students were required to develop a list of evaluation criteria for each assignment and to use the criteria to evaluate their work before submission. Based on this experience, we concluded that the students rarely produced a meaningful list of evaluation criteria. Despite our efforts to communicate the properties of a good evaluation criterion, most of the criteria devised by the students were ill defined. The criteria were frequently very generic, rather vague, and often failed to cover all of the essential aspects of the assignment. Another problem with this procedure was that although the students were explicitly instructed to *begin* their work with definition of the evaluation criteria, most of the groups defined the criteria at the end of the project. In that way, their work was not guided by any explicit set of goals and the developed criteria often fit better the final outcome rather than the assignment's requirements.

To ensure that the students appreciate the value of and benefit from a set of sound evaluation criteria, the process has been revised once more. In the recent semester (Spring 2004), we introduced a two-phased procedure to facilitate definition of evaluation criteria. Additionally, we increased the students' involvement in the projects' evaluation process. In the remainder of this section, we outline this procedure, supplying an example of a concrete project realized by students during the semester. Following, we discuss our experiences with the procedure.

Defining evaluation criteria & evaluating student work together with students

The rationale behind the developed approach is twofold:

1. We want the students to be able to formulate meaningful criteria and goals for assigned projects.
2. We want the students to understand that a set of well-defined evaluation criteria is critical for an efficient and successful performance of any project.

Both of these skills are essential not only for academic but also professional success.

[7] AS alone had responsibility for accepting the assignments at the time.
[8] 5 of the groups had to resubmit the work 5 or more times.

To address these concerns we implemented a procedure for performing in-course assignments that engages the students actively both in the definition of evaluation criteria and in the subsequent evaluation of the submitted reports. The procedure is outlined in Figure 1.

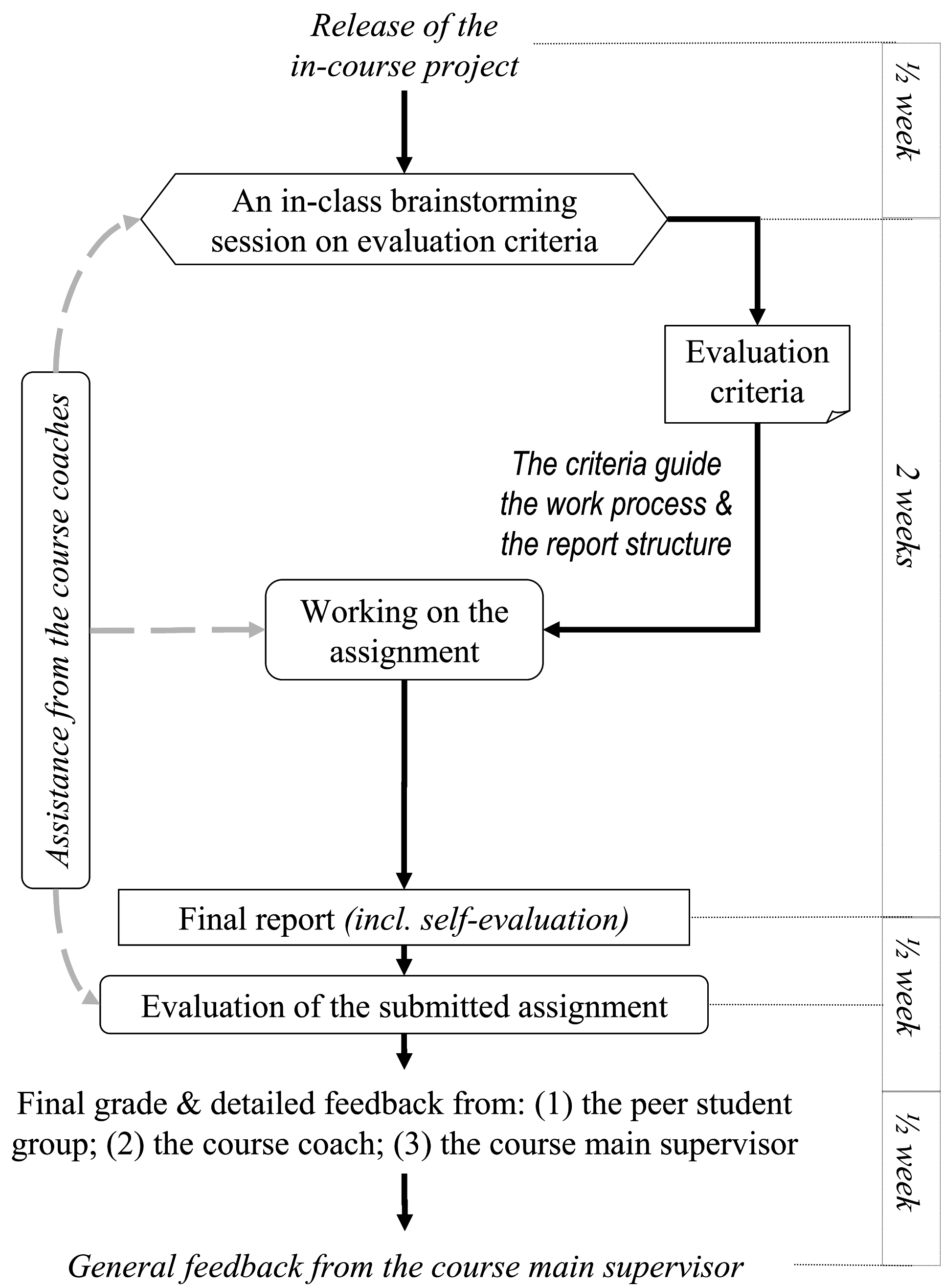


Figure 1 Outline of the in-course assignment process including definition of explicit evaluation criteria, self-evaluation and evaluation of the other student projects.

Before the obligatory project period begins, students are introduced to the concept of self-evaluation and the evaluation criteria-based procedure for carrying out and evaluating the assignments.[9]

While the difficulty of the obligatory in-course projects increases gradually over the semester, the basic structure of all the projects resembles the structure of the final examination project.[10] In that way, the students get continuous training in solving the type of problems they are likely to encounter during their exams.

The students are assigned the first "in-course" obligatory project in the second month of the term. The course running for four and a half months and the students are assigned a total of three to four obligatory projects during the semester. The projects are roughly evenly spaced along the time axis and run typically over two weeks.

As indicated in Figure 1, the students get the project paper three to four days before the project period start date. In Appendix A we reproduce the first project received by the students during this semester. Each obligatory project requires that the paper be based on quality criteria that are developed in a brainstorming process with the supervisors11 on the first day of each project. The quality criteria are made common and obligatory for all groups. Appendix B provides an example of the evaluation criteria developed for the project presented in Appendix A.

Every student group is required to structure the project paper in relation to the approved quality criteria. The last section of the paper must be a self-evaluation where the group describes the outcome for each quality criterion and proposes a reasoned grade for the corresponding item.

During the project period, the supervisors meet regularly with the student groups. Support is delivered as "help to self-help."[12]

After the papers are delivered, the supervisors and *selected student groups* mark the papers.[13] In a final meeting the main supervisor for the projects[14] assigns the final grade after considering the reports from another supervisor and the student groups who were assigned to marking the particular project.

The papers are marked using the very same quality criteria that were established for the project in question during the initial brainstorming session. The student groups get all explicit the markings from supervisors and the students groups who were assigned to mark the papers. The marking from the main supervisor is especially detailed in that it would settle possible disagreements in marking that might have come up between the other supervisor and student groups engaged in marking.

[9] The slide show used for the introduction is provided in the supplementary materials to the paper.
[10] An example of the final examination project is presented in Appendix E.
[11] Supervisors are, in addition to JJG (professor and responsible for the system dynamics course) and AS (Ph.D. fellow and assistant to the course), 2-3 so-called student assistants who are typically recruited among senior Master students, who already took the system dynamics course.
[12] In contrast, the final examination project is conducted without any kind of assistance from supervisors.
[13] Note that student groups are engaged to mark papers from other student groups. Each student groups has to do so at least once per term.
[14] This would be normally JJG as professor and main responsible for the system dynamics course itself, but sometimes the responsibility for the final grading of the in-course projects was assigned to AS.

A collected list of comments is compiled by the main supervisor and delivered to the class. The comments and markings are debriefed with the class, making sure that questions are answered and misunderstandings are removed. In Appendix C, we reproduce a set of final comments delivered for the project presented in Appendix A.

Our experiences

Many students find our approach demanding – although they seem to approve the whole idea.

Some students complaint that our approach requires much more time than what they perceive would be justified for a 10 ECTS credit course (which, remember, corresponds to one third of the half-year term). They would argue that the way system dynamics is taught goes at the expense of other courses in the term. We return to this point in the **Discussion** section below.

Such dissatisfaction is also reflected on the in-course evaluations. Students deliver two evaluations during the lecture period: The first comes six weeks after the course start and the second comes at the end of the lecture period but *before* the examination. A significant number of students (up to 30-40%) comment critically on the amount of work they perceive as required. On the other hand, negative comments as to the usefulness of the approach are not advanced.

As supervisors we observed that students participate actively in the debriefings and we register a clear improvement in quality of the papers during the lecture period. We like to interpret this as an indication that some sort of quality improvement process is occurring.

Another important indication of the approach's success is that repeatedly we observe the average examinations results for system dynamics students at Agder University College tilting towards the higher quality end of the scale for about one character grade during the course. As indicated earlier, the final examination projects resemble the in-course assignments.

An examination project consists of a challenging open-ended project and runs for five working days. Appendix D contains an example of the examination projects from the previous academic year.[15] As for the in-course projects, the examination papers require that quality criteria be explicitly developed and applied (including that each student group delivers a self-evaluation as part of the paper). Naturally, during the examination, each student group is responsible for developing and implementing independently a set of appropriate evaluation criteria. The proposed criteria and the way they are applied not only allow the students to increase quality of their work, but are among the project's aspects being evaluated.[16]

[15] The examination project presented in Appendix E was devised for Master students of Information and Communication Technology.

[16] It may be interesting to elucidate the final examination grading procedure applied within the Norwegian university system: The examination papers are graded by the professor responsible for the course (here JJG) and an external examiner (which, for the last four years has been associated professor Sigmund Nævdal, Institute for Information Science, University of Bergen). This grading system is considered to be more objective than single grading by the professor who was responsible for the course. In addition, such practice provides comparisons among institutions and is supposed to lead to more consistent results.

Some student groups improve for up to two character grades during the course. Particularly successful student groups have sent emails to the supervisors in gratitude for what they perceived as a worth-while experience with the “in-course” assignment procedure.

We are still dissatisfied that project papers tend to be longer than strictly necessary and they tend to contain irrelevant (or less relevant) stuff at the expense of essential pieces. But in comparison to more traditional approaches (as experienced before we developed this new approach) the students seem to read the project description quite accurately (judging from the significant reduction in overlooked or misunderstood items).

Another weakness of the approach is the level of frustration it seems to cause among the students, especially during the initial in-course projects. Many students are used to being required only to deliver their “best” response to the academic assignments. It is our impression that in their past experiences, only a few tried to plan and quality-assure in an explicit manner their submissions. As such process is rarely explicitly required, most students tend to jump straight into tackling the assignment without a moment of reflection and consideration of what it is they should work on and deliver. As indicated earlier,[17] in our previous routines, when we required each student group to define independently the evaluation criteria, only a few groups actually tried to develop the set of criteria at the outset of their work. Most of the groups treated the definition of criteria and self-evaluation as yet *another* part of the deliverables, and not as a vehicle for improvement of quality of their work.

The recent procedure imposing an obligatory definition and application of evaluation criteria (see *Defining evaluation criteria & evaluating student work together with students* section) ensured that the students’ work was indeed guided by the explicit quality criteria. Still, as indicated at the outs of the section, while approving the overall approach, a number of students perceive the amount of coursework as excessive. A discussion of the effectiveness of and possible improvements to our approach in this context would be especially interesting for us.

Discussion

The feedback that the students provide is mixed. As reported above, the course evaluation forms tend to have a significant of critical remarks, “far too much effort” being the running theme. On the other hand, we have observed that less than 100% of the students do deliver a course evaluation (which is voluntary). We have the subjective impression that students that are less satisfied with the course are less motivated to engage in the course evaluation.

The results in terms of the grades obtained by the students are encouraging. On the other hand, we have noticed that system dynamics is not a popular area for selecting Master theses. But again, those students who do opt for anchoring their Master thesis within system dynamics tend to know that the subject (and their supervisor!) is demanding and deliver above average results.

[17] For details, see the description of the procedure employed in the 2002/2003 academic year on page XX (UNDER TRACK CHANGES I CANNOT ADD BOOKMARKS).

The *leitmotiv* that the system dynamics course demands more effort than is perceived as appropriate (i.e. more than on third of the total time for the term) has recently forced us to think of the problem in terms of process improvement (Repenning and Sterman 2001). As employees in enterprises, to improve performance students can opt for working harder, increasing *Time Spent Working* (ibid., Fig. 2 – The "Work Harder" Loop) or to improve "capability" – i.e. working smarter (ibid., Fig. 3 – The "Work Smarter" Balancing Loop). Our expectation was that – in order to meet the demands posed by our project-based approach – students would look for ways to ways to work smarter.

This is not necessarily the case. As the great Polish satirical poet Stanislaw Jerzy Lec wrote: «People prefer thoughts that do not force them to think.» (Lec 1967)[18]

We do find some evidence for working smarter but not to the extent we had hoped for. In future versions of the system dynamics course, the in-course projects will demand that (beyond the self-evaluation process as described above) each project be executed within a maximum amounts of hours (to prevent the obvious "solution" of working harder to meet the demands, i.e. the recourse of expanding the amount of hours spent in the project). Student groups will be asked to document their priorities. We hope that this variant of the approach would improve the students' ability to detect and take account of essential points and lead them to work smarter – rather than harder.

Acknowledgement

The contribution from Agata Sawicka has been financed with a fellowship from the City of Kristiansand.

References

Coyle, R. Geoff. 1996. *System Dynamics Modelling: A Practical Approach*. London: Chapman and Hall.

Gonzalez, Jose J, ed. 2003. *From Modeling to Managing Security: A System Dynamics Approach*. Vol. 35, *Research Series*. Kristiansand, Norway: Norwegian Academic Press.

Lec, Stanislaw Jerzy. 1967. *More Unkempt Thoughts*. New York: Funk & Wagnalls.

Maani, Kambiz, and Robert Y. Cavana. 2000. *Systems Thinking and Modelling : Understanding Change and Complexity*. Softcover ed. Auckland, New Zealand: Pearson Education.

Repenning, Nelson P., and John D. Sterman. 2001. Nobody Ever Gets Credit for Fixing Problems that Never Happened: Creating and Sustaining Process Improvement. *California Management Review* 43 (4):64-88.

Richardson, George P., and Alexander L. Pugh, III. 1981. *Introduction to System Dynamics Modeling*. Portland, OR: Productivity Press.

Sterman, John D. 2000. *Business Dynamics : Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill.

[18] Stanislaw Jerzy Lec was a very imaginative and smart guy – also in practice. As Jew he was deported to a concentration camp by the Nazi Germans invaders of Poland. Lec stole a uniform and walked out dressed as German soldier ("unfortunately only lower rank" he used to say when he told the story afterwards) out of the concentration camp.

Appendix A

Project for IND404 & IKT406 System Dynamics

Deliverables:	**Well-documented and tested model(s) with paper**
Start of project:	**Monday 23 February 2004 at 09:00 am**
Delivery of paper:	**Friday 12 March 2004 at 04:00 pm**

About the Project

Background

This is the first of four obligatory projects. The four obligatory projects will count altogether 25% to the grade in the course in System Dynamics.

Pedagogic Goals of this Project

The course in System Dynamics has covered the basic methodology, including a thorough exposition of the principles for model development.

This project has several basic pedagogic goals. The staff in charge of this course (myself: Jose J Gonzalez, and the project coaches Ph.D. fellow Agata Sawicka, and student assistants Kristian Melhuus Brandser, Henning Arnold Jorkjend and Silje Salte) will help you achieve these goals – and we will test how well you achieve them.

1. The first pedagogic goal is to improve your ability of reading a problem description – experience from obligatory projects and examinations shows that the majority of students do not read sufficiently well the available information. This aspect – which in my experience is valid for all courses that I have taught during thirty years (in probability & statistics, mechanics, physics, computer science, software engineering, system dynamics, etc) – is crucial: Most students don't get the grade they hope to achieve, because they speed up to tackle the problem in question without having read carefully and digested the problem (or project) description. Your report will be analyzed for how well you have utilized the available information in the project description.[19]
2. The second pedagogic goal is to improve your ability to utilize other sources of information. You should find help for most of the issues of this project if you look up in the relevant chapters of the recommended book for this course, e.g. of John D. Sterman 2000. Business Dynamics : Systems Thinking and Modeling for a Complex World. Boston: Irwin/McGraw-Hill. Also, the course slides contain useful information. Accordingly, this project will also test if you are able to identify and use relevant information in literature that is at your disposition. Note, however, that your report must show that you have understood the information – just copying sentences, figures, etc from the book or the course slides is not good enough. Be aware, though, that there is

[19] Here you must make sure that you understand all words. If necessary, go to the available internet version of the Merriam Webster dictionary (or other dictionaries or lexica that are available to you).

some danger in following an existing model template too closely. The best method is to grasp the essential principles and develop your own model in a free manner!

3. The third pedagogic goal is that you apply successfully the basic methodology on a fairly simple case. In fact, the project case the case is much simpler than the case used in the Model Development section of this course. In order for you to succeed, it is required that you form a clear picture of what it means to develop a good model and how you assess it (both the model under development and the final result).

4. The fourth pedagogic goal is that you write a good report: It should be "to the point," containing all relevant information while you avoid including irrelevant information or too many words. To test how well you perform in this task, it is required that you form a clear picture of what it means to write concisely a good report and how you assess it. (*Concise* = konsis, kortfattet.)

5. The fifth pedagogic goal is to learn how to *evaluate by self-assessment*. This is a goal that concerns all the points above and it has been referred to several times: Defining and using a quality assurance system so that a) you form a clear picture of what characterizes a good project, b) evaluate if what you are doing while you are solving the project is matching appropriate quality criteria, and c) you change your course in time if you are going astray.

Note that all goals have general validity for *any* subject you are learning – in fact for any task that you are solving – no matter which course. In fact, they have validity for any task that you will be solving in your professional life.

Evaluation by self-assessment

We will use evaluation by self-assessment in the obligatory projects (and in the final examination paper as well).

Evaluation by self-assessment serves three important purposes:

1. It is a quality assurance criterion that will help you achieve a good result.
2. It will give meaning to what you are doing and you will understand and learn better: You will be *working smarter*!
3. You will propose the grade for your project! The project coachs (in addition to me, it will be Ph.D. fellow Agata Sawicka, and student assistants Kristian Melhuus Brandser, Henning Arnold Jorkjend and Silje Salte) as well as selected student groups will read your report and your evaluation and give you their grading. This feedback will make you learn and become more conscious of what is a good result, thus letting you improve during the course.

Wednesday 18 February at 10:00 a.m. in Aud F you get an introduction to the principles of evaluation by self-assessment. PARTICIPATION IN THIS SESSION IS OBLIGATORY FOR ALL PROJECT GROUPS!

Appendix A

Monday 23 February at 09:00 am all groups meet in Aud F. Guided by the project coachs Ph.D. fellow Agata Sawicka, and student assistants Kristian Melhuus Brandser, Henning Arnold Jorkjend and Silje Salte, you participate in a process leading to the binding definition of evaluation categories and evaluation criteria for the project. PARTICIPATION IN THIS SESSION IS OBLIGATORY FOR ALL PROJECT GROUPS! In fact, participation – not only being there but also been active – is very much in your own interest. Otherwise you risk letting *others* define what is good for you and you risk also that you do not know well the binding evaluation categories and evaluation criteria that will be applied to determine your grade.

The Paper

The paper – the report that you write – is the main deliverable. The model or models that you develop are intermediate stages, but what counts and what will be used to evaluate your project is your *paper*.

Note:

1. We require that you deliver both your paper AND your model(s). But nevertheless, the models will only be used if it is necessary to check some point in your report. In other words: EVERYTHING THAT YOU WANT THE READER OF YOUR REPORT TO BECOME AWARE OF MUST BE IN YOUR REPORT!
2. This said – and because your paper must be as short as possible – you should use references whenever possible. For example: Instead of putting in your report the documentation of all units and variables, you can pick the most interesting ones for your report and then refer to the model for the documentation of all the others.
3. The recommended size of the paper is no more than ten pages of text or even shorter, if possible. In addition you can have good figures and tables, when necessary. Feel also free to add a list of contents or other items that make your paper well-structured and easier to read. In your own interest, you should make an effort to use (moderately) "advanced" features of your word processor such as e.g. creating the structure of your document with the outlining facility.

The Final Grade

As stated above, the final grade will be assessed by the process coaches and selected student groups (in fact, 50% of the groups – the other 50% will assist in the evaluation of the next project).

Be aware that we will inspect your paper for originality: If we find that your paper reminds suspiciously of what is found in other papers, this will lead that both papers will get a lower grade. In other words, while it is important that you share ideas WITHIN your group, the fact that the project counts as part of the grading of the course means that there should NOT sharing of ideas ACROSS GROUPS.

Project Specification

The concept that some resource grows through contact between two states of the resource is very powerful. You have seen this concept in action in the word of mouth

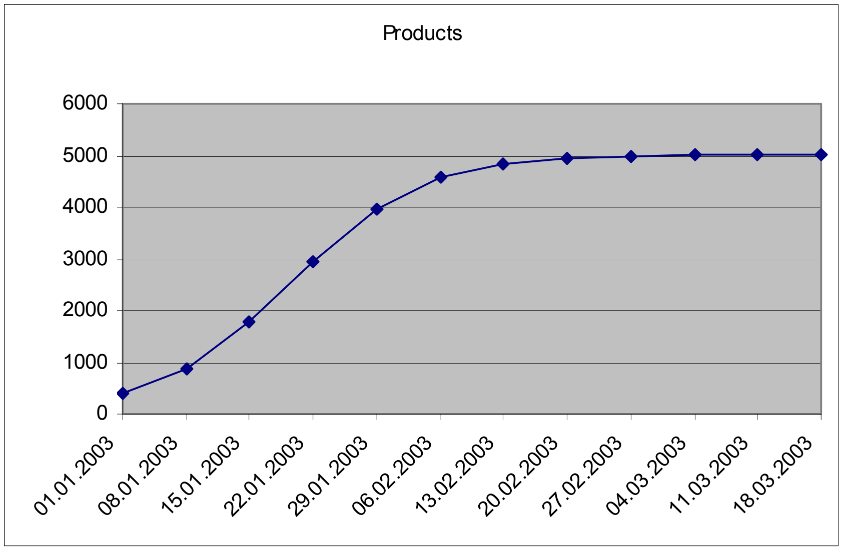
Appendix A

principle acting to power the spread of i-mode devices in Japan. Other cases that can be described by a similar mechanism are e.g. infection of PC's by computer virus and spread of an idea or an innovation.

In the present project, the case is sales of a high-tech product in a region.

Assume that a certain hi-tech product has been sold in the Agder province as follows:

Time	Products
01.01.2003	400
08.01.2003	882
15.01.2003	1775
22.01.2003	2950
29.01.2003	3972
06.02.2003	4570
13.02.2003	4840
20.02.2003	4945
27.02.2003	4984
04.03.2003	5001
11.03.2003	5006
18.03.2003	5009



(Notice that the calendar used is the bank calendar, where a "year" consists of 12 "months" of 30 days each.)

We will use the above data (see the enclosed file) for constructing a system dynamics simulation model. In relation to such a process:

1. Explain how such data is used in the system dynamics modeling process. What is the name used in system dynamics for the data given above?
2. What is the time horizon for the problem?

Assessing the Curve

It is obvious that the sales curve has S-shape. But there are many possible forms of S-shapes.

To understand what kind of S-shape the sales curve is, and in order to develop a good simulation model you need to do the following:

1. Make a reasonable estimate of the market size for the high-tech product in question in Agder. You should substantiate your estimate with a short argument. (No need to use advance methods here!)
2. Assume that the growth rate of the sales curve is given approximately by the equation $g \bullet (1 - S/M) \bullet S$, where S is the number of products sold at any time, M is the estimated market size and g is some constant. Choose a part of the

sales curve around the inflection point (why?). What value do you get for *g*? (Make sure that you give the right units for *g* as well!).

Causal loop diagram

Based on the information gained above construct a preliminary causal loop diagram that is able to explain qualitatively the problem behavior. In other words, you should identify the feedback loops of the model and explain how they are likely to determine model behavior.

Be aware that a good solution demands a good interpretation of the proportionality constant *g*. Make a good assumption backed up by some appropriate reasoning.

<u>Hint</u>: If you are stuck, look for help in the materials available to you. But don't forget to express the ideas in your own terms.

Stock-and-Flow Model

This section will include many aspects. In your paper it is convenient that you break down the aspects into well-structured pieces (that are present in your document as chapters, sections sub-sections or similar concepts).

All in all, this "Stock-and-Flow Model" section concerns model development, including (but not being restricted to) stock-and-flow model building, model verification, incremental testing & validation, final model validation, policy aspects,… as well as overall aspects like "good practice" as has been demonstrated in the many interactive examples during the course). In addition, it is expected that you calibrate the model parameter (or parameters!) so that your model is able to replicate the sales data with good accuracy. (You should state your goal for good accuracy and argue for that – i.e. not just saying "we opted for so-and-so-much accuracy.")

Another important issue that you should not overlook is to include a good explanation of model behavior in terms of feedback loops. Note that this aspect is relevant both *before* you build the actual stock-and-flow model (i.e. as guiding hypothesis) and *after* the stock-and-flow model has been built and you are able to run it (i.e. in terms of proving the actual relationship between feedback structure and dynamic behavior).

Appendix B

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*
Student Group:

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Problem presentation	Problem identification			
	Reference Behaviour Mode			
	Causal Loop Diagram (CLD)			
Modelling	Model structure and its relation to problem specification			
	Model variables			
	Time step			
Testing /validation	Reference behaviour test			
	Extreme value testing			
	Incremental testing			
	Model calibration			

Appendix B, cont.

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*
Student Group:

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Model analysis	Analysis of the dominating feedback loops and model behaviour.			
	Policy analysis and recommendations			
Paper	Structure			
	Conciseness			
	Wording			
Self-evaluation	Process documentation			
	How you argue for the grades			

Total grade:

Appendix C

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*

<table>
<tr><th>Evaluation category</th><th>Criteria</th><th>Comments</th><th>Sub Grade</th><th>Grade</th></tr>
<tr><td rowspan="3">Problem presentation</td><td>Problem identification</td><td>1. The problem is formulated as ”to develop a SD model that reproduces the Reference Behaviour Modes. But we don’t model for modelling itself. SD models must be more than descriptive models: They must provide insight into the connection between structure and behaviour and lead to policy recommendations.
2. One must not mix up the description of the problem with the problem analysis.</td><td></td><td rowspan="3"></td></tr>
<tr><td>Reference Behaviour Mode</td><td>1. The reference behaviour must be given explicitly.
2. One must not mix up the description of the reference behaviour with the problem analysis.</td><td></td></tr>
<tr><td>Causal Loop Diagram (CLD)</td><td>(Strictly speaking this criterion should have been made part of the Modelling Part – a mistake on part of the supervisors)
1. The reasoning leading to the CLD must be given. The reasoning should be based on the given reference behaviour.
2. The loops in the CLD must be labelled.</td><td></td></tr>
</table>

Appendix D, cont.

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Modelling	Model structure and its relation to problem specification	1. The reasoning leading to the stock-and-flow model is often deficient or lacks completely 2. The reference behaviour mode must assist model building and help determine model structure. 3. The constant *g* is not intuitively clear. It should be explained as product of contact rate and buy probability. I don’t agree with the contention that one can only use g because the reference behaviour data does not allow to estimate the values of contact rate and buy probability separately. Apart from added insight, using contact rate and buy probability gives a better platform to discuss potential policies. E.g., the huge success of the Japanese i-mode mobile phones was facilitated by features that both increased the contact rates between teenagers and the probability that Word-of-Mouth would lead to sale.		
	Model variables	Best: Table with good names, variable type, variabel definition (equation/value if constant) and explanation/variable documentation.		
	Time step	Many choose *dt=1 <<wk>>* because the reference data is given for weekly intervals: Bad Argument and bad choice! The desired accuracy should determined the value of the time step. *In this case we choose visual accuracy*.		

Appendix D, cont.

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Testing /validation	Reference behaviour test	1. This is an important criterion that is related to the calibration process. The outcome must be a model with certain values for the model constants and initial values so that the deviation between model results and reference data is minimized. 2. Ok method: Table depicting the deviations (Better method: the least squares method).		
	Extreme value testing	Each extreme test must be based on some case where it is possible to predict the outcome without actually simulating. Afterwards, it must be shown that the model simulation gives the expected result – otherwise there is an error in the model.		
	Incremental testing	Many groups state that they did test incrementally while the model was built. This is not sufficient: One must describe how this was done.		
	Model calibration	1. Some groups confused parameter calibration with determining the time step. 2. Desired outcome: A description of the process how you accomplished the reference behaviour test-		

Appendix D, cont.

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Model analysis	Analysis of the dominating feedback loops and model behaviour.	Some groups forgot this point, believing that it was sufficient to analyze the loops when constructing the initial CLD-		
	Policy analysis and recommendations	Many groups overlooked or misunderstood this part. *SD models must be more than descriptive models: They must provide insight into the connection between structure and behaviour and lead to policy recommendations.*		
Paper	Structure	1. Good results for most student groups. Best results when the paper was structured in close consideration fot he evaluation form. 2. Most student groups seamed to have read the project very well – a clear improvement from previous practice- 3. Some papers include discussions of topics as found in books or lecture notes (e.g. about CLD). *The paper msut concentrate on the project!*		
	Conciseness	Most groups did perform well		
	Wording	1. Satisfactory results for most student groups. 2. Some inaccurate wordings such as … [EXAMPLES WOULD FOLLOW]		

Appendix D, cont.

Evaluation Form: Obligatory project #1 *(Deadline: 2004.03.12)*

Evaluation category	*Criteria*	*Comments*	*Sub Grade*	*Grade*
Self-evaluation	Process documentation	Very weak point for most student groups: Without a clear process documentation you won't be able to improve your performance.		
	How you argue for the grades	1. Most groups are uncritical: Insight and self-criticicism is a precondition for improvement. 2. Difficult/some times impossible to understand how you determined your grade. Often the proposed grades seem arbitrary. 3. Because of the previous point it is difficult/impossible for you to improve. If your grading is arbitrary, there is no rationale and no way to determine how to improve.		

Total grade:

Appendix D

Examination Project for "IKT1200 System Dynamics"

Deliverables: **Electronic version of report and model file**
Start of project: **Friday 23 May 2003, 2 pm**
Delivery of project: **Wednesday 28 May 2003, 6 p.m.**

Important

Delivery

You must email your project files (report plus model) within 6 p.m. of Wednesday 28 May to Jose J Gonzalez AND sensor Sigmund Nævdal.

Dictionary

It is crucial that you understand every word, so if you have problems go to the dictionary Merriam-Webster Online.

Language

You can choose whether to answer in Norwegian or English. (It is best to use English since you avoid having to translate concepts from this document and the attached report from English to Norwegian).

Content of the examination paper

Your examination paper must contain the following obligatory sections:

1. Your suggested criteria for self-evaluation of the project
2. Project plan (see § 4.2)
3. Establishing the validity of the problem analysis
4. Conceptualizing the system dynamics model
5. Description of the main features of the model
6. Analysis of model behavior
7. Model-based proposals for preventing or reducing the impact insider attacks
8. Your self-evaluation of the project according to the criteria from point 1.

(If you find it necessary you can add more sections but they are not strictly necessary.)

The points are given in a specific order because of good reasons. Specifically, the criteria for self-evaluation are intended to help you to stay focused and on track. That is why they must not be "invented" at the end of the project – even if the *result* of your self-evaluation must come at the end.

As to point 8 – self-evaluation – use the new scale A-F according to the criteria given in Veiledende retningslinjer for bruk av felles karakterskala ved ingeniørutdanningen, sivilingeniørutdanning og maritim høgskoleutdanning.

Appendix D, cont.

Description of the Examination Project

Information security case

The Tim Lloyd/Omega Case is a famous case of insider attack to an information security system (see the enclosed report 'The Tim Lloyd_Omega Case Study.pdf' by Sharon Gaudin). As a first step, you must read Gaudin's report very thoroughly because the examination project consists in identifying the parts of this information that are necessary for modeling the problem.

In other words, you must find out *relevant* information and disregard information that is *not relevant*. Such task is common and frequent in real life projects: You get a lot of information, but you need to stay focused and put your finger on the important things while ignoring the things that are not important.

You should not be scared: In the following you find hints that help you to make the right decision. Again, the crucial issue is to read the materials well and to stay focused.

About the analysis of a problem

The analysis of a problem is the result of collecting focused information about some problem, organizing and structuring the information, identifying reference behavior, time horizon, intended use of the model, target group, etc. This is normally the most difficult part of a modeling process (and – for that matter – of any problem-solving process). Once you have a good analysis of the problem, modeling becomes quite easy.

In the IKT1200 course we called such process "problem description" (with its associated aspects of reference behavior, etc). In Sterman's book you find it in §3.5.1-3.5.2 – but there you find also stuff that you don't need today.

In this case you are *not* asked to write down the analysis of the problem yourself. Rather, you are given an analysis and your task will be to look in Sharon Gaudin's report of the Tim Lloyd/Omega Case for information that supports the formulations found in the analysis below. (If you don't find supporting information then you should consider that part of the analysis as an *assumption* and discuss how good the assumption is.)

Your task is to write a section ("Establishing the validity of the problem analysis") in your report about the analysis of the Tim Lloyd/Omega Case. For this you have to:

- Go step for step through the analysis below and scan Gaudin's report for supporting arguments (note that the arguments may be scattered, i.e. that part of the supporting argument may be on page 2, say, and other part on page 5).
- Quote specific information from Gaudin's report and use that to provide arguments in support of the formulations used in the analysis.
- Note that sometimes the arguments you find in Gaudin's report are strong, sometimes they are less strong, sometimes they are weak and – it may happen – sometimes no arguments are found. Hence, in addition to find and assemble arguments and make clear, unambiguous references to Gaudin's report, you must also critically evaluate the arguments. In other words, you should state whether the supporting argument is very strong, strong, less strong, etc.

Appendix D, cont.

- Make assumptions if necessary. That is, if you are not able to find evidence in Gaudin's report that directly supports some issue in the analysis, then you will have to consider the issue to be an assumption. In such a case you must discuss whether the assumption is reasonable or not, whether there might be other possible assumptions and what their relative merits are.
- Finally, you must find reasons (and discuss their validity) in support of the graphs of the reference behavior mode (Figure 2).

Analysis of the Tim Lloyd/Omega Case

Synopsis of the case

Before the preparation and execution of the "big attack", Tim Lloyd caused the occurrence of some incidents that affected proper operation of the information system and caused *downtime*. Arguably, in the absence of controls, management would perceive downtime as an indicator of security level. Since downtime seems to have occurred rarely in the past, and had not been very serious, management was not concerned so much about security. Omega seemed to have an acceptable security level, and from this sense of complacency Omega's security became victim of its own "success."

In the time before the attack, Omega was expanding from a local company into a global enterprise. There was a high pressure on the company to grow its business during the entire time horizon under consideration. The high pressure to grow is likely to have diminished management's commitment to security. Low commitment to security and misperception of the security level meant that management actions to improve or, at least, maintain the security level were grossly inadequate.

Tim Lloyd quarreled and caused workplace discontent. The precursor incidents of Tim Lloyd and the downtime they generated also caused workplace discontent. Workplace discontent seems to have worried management the most because it affected productivity directly. Management took some actions to stop these incidents and improve workplace climate: Tim Lloyd received verbal and written warnings, and was demoted. However, there is no evidence to the effect that management perceived Lloyd's actions as threats to security. Rather, there is clear evidence that management interpreted Lloyd's behavior only as a threat to workplace climate while continuing to trust him completely as a computer expert.

As a malicious insider, Tim Lloyd had the advantage of being able to reduce the security level through actions derived from his knowledge of the system.

Time horizon

Aiming to describe Lloyd's actions and their consequences we shall consider as time horizon for the model to be the period from early 1995 until the end of July of 1996, or – for convenience – from 1 January 1995 to the end of 1996.

Appendix D, cont.

Model boundaries

The model boundaries will be drawn around the insider and Omega's management, their perception of security and its influence over the security level. We assume that Omega had a malicious insider and we analyze which factors provoked a successful attack.

Reference behavior

Following his demotion from a star employee to an average worker, Tim Lloyd exhibited public signs of discontent. He became "an angry man who lashed out, verbally and physically, at his co-workers, bottlenecked projects simply because he wasn't in charge of them, and even knowingly loaded fault programs to make coworkers look bad, according to Omega executives. In that year, he had received verbal warnings, was written up twice and demoted.

A crucial observation is that management perceived Lloyd's problematic behavior as a disruption of workplace climate and not at all as a threat to the security of the company.

Management's total obliviousness concerning Tim Lloyd as a threat to Omega's security is astonishing because Lloyd did cause some problems to the computers and the networks, upon feeling being disrespected.

Accordingly, the reference behavior modes include Tim Lloyd's disruptions of workplace climate as well as some security incidents that went unnoticed as security threats. Further, the reference behavior includes management preoccupation with workplace climate and corresponding obliviousness toward the security threat posed by Lloyd. It is likely that the high pressure to grow, which had characterized Omega since 1985, made workplace climate the key aspect of concern for management.

There was an absence of formal security policies (designing correct segregation of security duties, designing and controlling an appropriate employee-supervisor relationship). Neither are there clues about any security audits: The deliberate "markers" (here, problems to the computers and the networks) by Lloyd stayed unnoticed as security threats. Therefore, we assume that security audits did not exist.

Tim Lloyd made up his mind to strike some months in advance of the "big attack." His disgruntlement may have triggered his actions to reduce the security level of the system. About a year before he committed the attack, he showed visible signs of discontent, and the failure of management to respond to this behavior from a security perspective may have encouraged Lloyd to plan his attack. Lloyd's behavior and his actions to disrupt the information system can also be interpreted as deliberate markers to test whether such behavior and manipulations would provoke management suspicion of an insider attack. Management's failure to react to these markers was a clear sign that nobody seemed to be concerned about information security at Omega. This lack of concern let Lloyd act with impunity to make the system more vulnerable in the few months before he committed the attack. Interestingly, Mitnick and Simon ("The Art of Deception". 2002, see e.g. p. 20-21) document that probing the alertness of defenses through appropriate "markers" is part of the "bag of tricks" of malicious agents.

The security level was extremely low at the end of the considered time horizon, i.e. when the attack actually occurred. The security level had decreased significantly during the last few months preceding the attack.

Graph of reference behavior

The figure below gives a *qualitative* idea of the problem's reference behavior. Since the available information on the Tim Lloyd/Omega Case is *qualitative*, the graphs below are *qualitative* too. Notice, e.g. that Tim Lloyd's precursor incidents are given as approximately regularly spaced pulses of the same height.

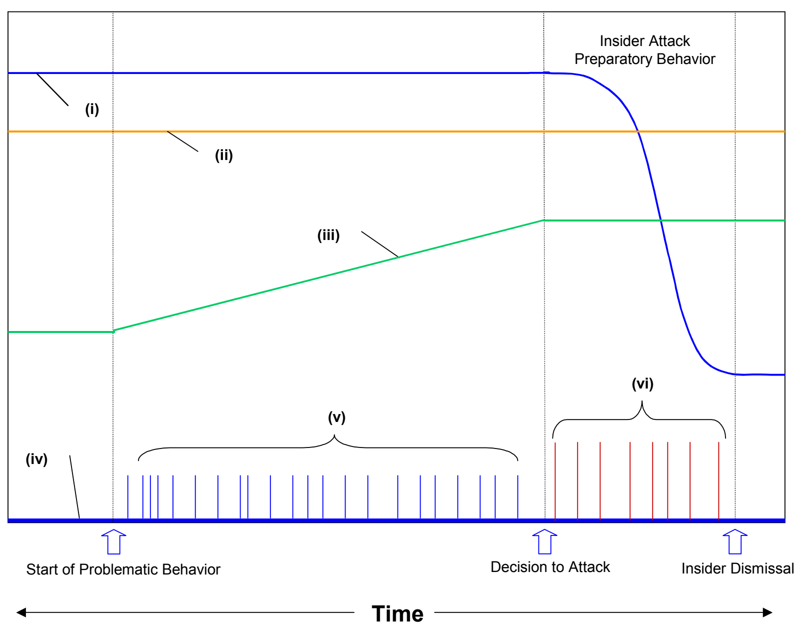


Figure 2 Reference Modes: (i) Security level; (ii) Pressure to grow; (iii) Workplace discontent; (iv) Formal controls; (v) Disruptions of workplace climate and precursor incidents; (vi) Actions to reduce security level. The time bomb fires off at the very end (not shown).

Dynamic hypothesis

The dynamic hypothesis is that insider attacks tend to occur when potential malicious insiders perceive the system as being extremely vulnerable. In the case of Omega, risk misperception and management priority on growth over security provoked an erosion of standards that led Omega to a low level of security.

Apparently, the malicious insider perceives this security exposure in an accurate manner and this reinforces the probability of attack. The insider tests the alertness of the system with "markers", i.e. creating small disruptions. In fact, it is likely that the intent to launch a big attack originates gradually when small disruptions motivated by the insider's discontent fail to be detected by management, thus indicating to the insider that the system is vulnerable.

Further, the accurate perception of the system's vulnerability, including the observation that nobody seems to care, induces insider actions to maximize the impact of the attack without being detected. For example, as in Lloyd's case, to conduct a test attack before the 'big attack' or to take the programs off the workstations and centralize them in just one file server. These actions to probe the system's defenses can be interpreted as part of the insider's preparatory behavior before launching a full-scale assault.

Conceptualizing the system dynamics model

From the analysis and the reference behavior given above you should generate a preliminary list of the main variables of the model. (Main variables means: The most important ones, those that are the core of the model and get you started.)

Stick to the main variables (no more than absolutely necessary). Find a good name for them and their unit of measure (if any – they may be unitless in some cases).

In the Appendix you find some hints to get started.

Give in your report your list of main variables with their names, units (if any) and a short documentation.

Description of the main features of the system dynamic model

After developing a *simple* system dynamics model that qualitatively reproduces the reference behavior mode (Figure 2) you should describe it. Make sure that you put good figures of the main elements of the stock-and-flow model in your report and that you give a short description of the model structure

It is not necessary to list *all* variables but you can add a description of important variables that were identified *after* the preliminary analysis from the previous section.

Analysis of model behavior

Show simulation runs and compare with the reference behavior of Figure 2. Discuss and analyze the model behavior.

Model-based proposals for preventing or reducing the impact insider attacks

From the model (including the problem analysis above) discuss lessons for preventing insider attacks or – if an attack happens – for reducing the impact they may have.

Recommendations for organizing your project

Reading

It should be unnecessary to point out that you ought to read very carefully this document, including the description of Tim Lloyd/Omega Case. You should read it several times, and discuss it with members of your project group, aiming at getting hold of everything and developing shared understanding of what should be done.

Project plan

After having made a clear and well-focused specification of your examination project you should next develop a project plan. The project groups consisting of two/three people, you should make a plan for tasks that must be tackled together and for tasks where group members can work in parallel. Specify in advance the estimated duration of each task and try to stick to the deadlines. All this (including who works with what) must stand in the project plan – and it must come into the project report.

It is crucial that your project plan specifies and enforces *division of labor* – otherwise the examination project becomes too big. Make sure that the plan is dynamic, that you are able to make adjustments if some part becomes more demanding than anticipated.

Not "*The Answer*™"

Be aware that there is not something like "the one and single answer" – rather it is a matter of making well-founded choices for what to aim at, what to include & what to leave out in order to meet your goals, etc.

Working smart vs working hard

Be aware that there are several opportunities for saving time if you organize your project well through *division of labor*: E.g. modeling can be done in parallel with establishing the validity of the problem analysis. Try to find similar solutions for other tasks.

Deliverables

- An examination paper (report) AND a Powersim Studio model

The delivery must be in the form of files that you email within the final deadline to Jose J Gonzalez AND sensor Sigmund Nævdal with two attachments:

1. A Microsoft Word file of the examination paper (report)
2. A file with the Powersim Studio model

Everything you want the jurors[20] to become aware of must stand in your examination paper: Referring to the model file and asking the jurors to open your model is not acceptable! The point of your delivering the model is to allow the jurors to check aspects of your work as well as making is possible to find out about issues if it turns out that they are not clear enough described in the paper.

Grading

To grade your work one has appointed jurors that know something about modeling and simulation with the system dynamics method. The jurors will like to read reports

[20] Det vil si, Gonzalez og den eksterne sensor.

Appendix D, cont.

- that demonstrate that you master the method (as opposed to just being able to use the simulation tool);
- that you have a grasp of how system dynamics can be used to model intermediate to advanced issues in security;
- that you can communicate models and model behavior to an audience with a good knowledge of basic system dynamics.

Be aware that the jurors will be very strict against illegal cooperation between groups. Hence, the jurors[21] will compare the reports and models delivered by the various groups in order to detect suspicious similarities!!!

Appendix

It is recommended that you build up your models from sub models dealing with:

1. The effect of the incidents caused by Tim Lloyd's (the *insider*) on the information system downtime.[22] Each initial incident (precursor incidents) causes a little downtime and the single final, "big attack" must have disastrous consequences on downtime.
2. The effect of the insider actions on workplace discontent (it is convenient to introduce a unit of discontent, discontent being a soft variable).
3. The security level of the system. Introduce a unit to measure the security level: Actions like centralizing software, removing backup tapes, etc, should be described in terms of the value of the security level variable.

Try to find ways to figure out how the sub models should behave and remember to do incremental development and testing.

You need to consider how the insider and the management view the situation. The insider feels himself unjustly treated, he is "pissed off", he acts first impulsively, out of anger, quarreling a lot and causing some minor security incidents and at the end he acts with premeditation. Indeed, the insider's discontent stays very high and at some time Tim Lloyd understands that he *never more will be happy at Omega*. This happens *before* management – because of the perceived deterioration of workplace climate – decides to fire the Tim Lloyd.

You need to model the different perceptions of the insider and the management and how such perceptions – when they surpass some thresholds (one for Tim Lloyd, a different one for the management) – trigger some decision.

It is crucial that you take account of the insider's preparations. The insider developed the time bomb in advance so that the only thing left for him when he was fired, was to program the date when the time bomb should fire off. Also, the insider debilitated the information system so that the impact of the time bomb should be maximal.

[21] Det vil si, Gonzalez og den eksterne sensor.
[22] Downtime: Time during which production is stopped.

Appendix D, cont.

Consider how to model this so that the system on the one hand is technically weak, on the other hand that this is not discovered by the management (or colleagues).

Also, you need to find a consistent way to determine the date for the time bomb (without using knowledge of the fact that the time bomb was fired the 31st July 1996). (What makes Tim Lloyd fix the date of the "big attack" and when does this occur?)

The insider actions (security incidents, quarreling) should be modeled as pulses, the height of the pulse having relation to the impact of the action (on downtime or on workplace discontent). Do not bother to make the pulses random in time. Just make the precursor incidents regularly spaced in time.

Finally, if you get stuck with the stock-and-flow model you should – as second best solution – develop a causal loop diagram for the particular sub model and discuss it.